PHYSICAL AND HYDROCHEMICAL EVIDENCE OF SURFACE-WATER/GROUND-WATER MIXING IN AND NEAR LAKE SEMINOLE, SOUTHWESTERN GEORGIA AND NORTHWESTERN FLORIDA

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Abstract. Water resources of the Lake Seminole area in the lower Apalachicola–Chattahoochee–Flint River Basin emanate from an interconnected aquifer-stream-reservoir system that is centered around a constructed lake in a karst hydrogeologic setting. Ground water enters stream channels and the lake bottom by diffuse leakage and springflow; this water contains dissolved minerals from carbonate formations of the Upper Floridan aquifer. Water samples from wells adjacent to Lake Seminole contain higher concentrations of calcium and magnesium, and higher alkalinity and specific conductance than surface-water samples, which contain relatively high concentrations of total organic carbon and sulfate. Each of the four impoundment arms of Lake Seminole has a distinct water chemistry that can be attributed in part to the hydrodynamic connection of the lake bottom with the ground-water flow regime. Water chemistry and incremental discharge measurements in the Spring Creek impoundment arm indicate predominant ground-water discharge from the Upper Floridan aquifer into the lake. Chemical analyses and physical properties of water sampled from the dam pool and Apalachicola River indicate upwelling of lake water in the river downstream of Jim Woodruff Lock and Dam.

INTRODUCTION

Lake Seminole is a 37,600-acre reservoir that was created by the U.S. Army Corps of Engineers in the mid-1950's by constructing the Jim Woodruff Lock and Dam. The lake impounds the Flint and Chattahoochee Rivers near their confluence at the Georgia–Florida State line (fig. 1) and forms the headwaters of the Apalachicola River. The principal rivers of the lower Apalachicola–Chattahoochee–Flint (ACF) River basin are hydraulically connected to karstic and dolomitic limestone formations of the Upper Floridan aquifer and to carbonate residuum and alluvial deposits of the undifferentiated overburden, deriving baseflow from ground-water discharge from these units. The Upper Floridan aquifer underlies about 6,800 square miles of the lower ACF River basin and is one of the most transmissive and productive carbonate aquifers in the United States. Ground water is utilized extensively in the study area for agricultural, industrial, and domestic uses; such uses have been shown to reduce ground-water flow to streams (Torak and others, 1996; Torak and McDowell, 1996).

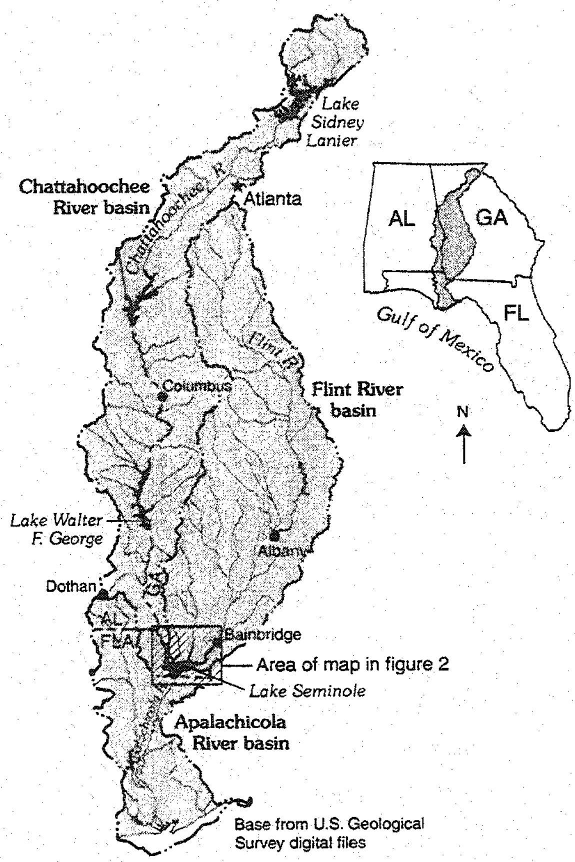


Figure 1. Location of Lake Seminole and the Apalachicola–Chattahoochee–Flint River basin, southwestern Georgia and northwestern Florida.

Recently, the lower ACF River basin has become the object of water-allocation negotiations between the states of Alabama, Florida, and Georgia (U.S. Army Corps of Engineers, 1999). Most of the ground water in the Upper Floridan aquifer originates as rainfall that enters the limestone directly through sinkholes or indirectly by infiltration through undifferentiated overburden. Sever (1965) estimated that 670 million gallons per day (Mgal/d), or 22 inches per year, of the region's annual 52-inch average rainfall recharges the Upper Floridan aquifer in the study area; of this amount, about 590 Mgal/d is not transmitted outside the study area under existing hydraulic gradients, but is discharged through springs into Lake Seminole.

In July 1999, the U.S. Geological Survey (USGS), in cooperation with the Georgia Department of Natural Resources, Environmental Protection Division, began a study to develop a water budget for Lake Seminole that incorporates surface-water and ground-water inflows and outflows, and atmospheric processes. This paper describes physical and hydrochemical evidence of surface water mixing with ground water in and around Lake Seminole. This information will help explain the origin and distribution of chemical constituents in the water resources of the Lake Seminole area and provide insight to the relative magnitude of water-budget components in the aquifer–stream–reservoir system.

Methods

During late-February and early-March 2000, 44 water samples were collected from wells, springs, streams, and Lake Seminole using standard sampling techniques of the U.S. Geological Survey (Wilde and others, 1999). Water samples were analyzed at USGS National Laboratories in Arvada, Colo., and Ocala, Fla., for major inorganic ions and total organic carbon (TOC) (fig. 2). At some stream sites, calcium (Ca) and magnesium (Mg) concentrations measured in water sampled in June 2000 were substituted for the late-February, early-March results, because samples were not collected during the earlier sampling period.

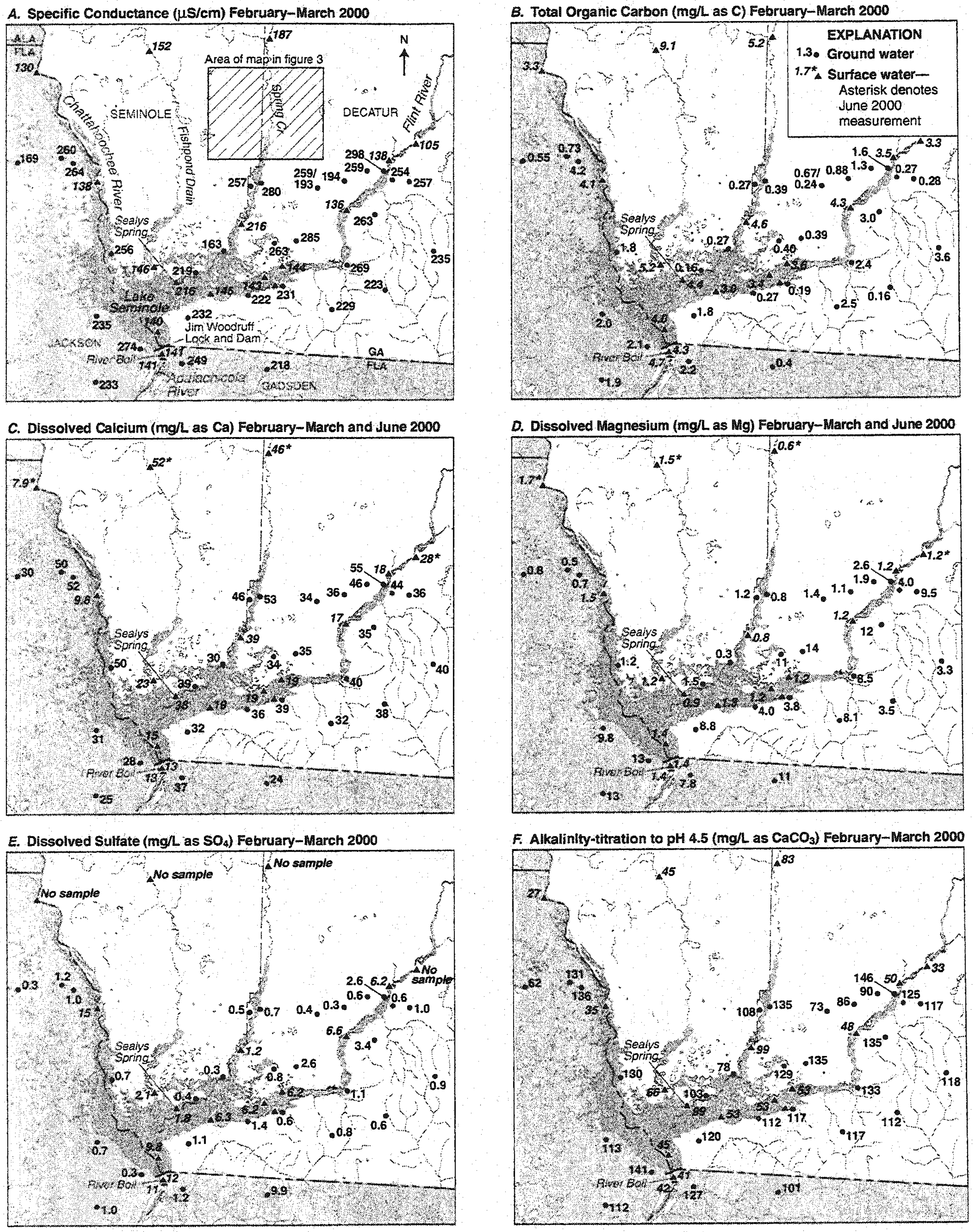
Water levels were measured in wells and stream stage and discharge measurements were made along springs and streams in October 1999, and in April, August, and September 2000. In September 2000, discharge measurements were made along the Spring Creek impoundment arm of Lake Seminole using conventional discharge-measuring techniques and acoustic Doppler current profiling.

RESULTS

Analyses of water samples from wells, springs, streams, and Lake Seminole indicate that ground water has higher values of specific conductance and alkalinity, and higher concentrations of Ca and Mg than surface water, which contains higher concentrations of TOC and sulfate (fig. 2). These results are particularly evident for Sealy's Spring (fig. 2), which, although located in the bottom of Lake Seminole, contains chemical constituents that indicate a ground-water origin. Higher concentrations of chemical constituents in ground water than in surface water are consistent with carbonate dissolution of limestone (Ca and Mg carbonate) units that form the Upper Floridan aquifer; an increase in TOC is consistent with organic enrichment of surface water (Appelo and Postma, 1994).

Stream-discharge measurements and flow from numerous springs along Spring Creek indicate that most flow into Lake Seminole from the Spring Creek impoundment arm originates as ground water (fig. 3). Additional physical evidence of ground-water flow into Spring Creek and Lake Seminole is indicated by the water level in wells surrounding the Spring Creek impoundment arm (fig. 4); these were higher than lake level during all periods of measurement in 1999 and 2000. Water chemistry corroborates physical evidence of ground water mixing with surface water, because water from wells adjacent to Spring Creek contain chemical constituents in concentrations that are similar to water sampled from the creek (fig. 2).

Physical and hydrochemical evidence of ground water mixing with surface water exists in the Apalachicola River directly downstream of Jim Woodruff Lock and Dam. Here, water containing concentrations of chemical constituents similar to lake water "boils" up from the Upper Floridan aquifer at a discharge point in the bottom of the river (fig. 2). Apparently, water from behind the dam enters the Upper Floridan aquifer by leakage through the lake bottom, then flows in the aquifer beneath the dam, subsequently discharging through the channel bottom of the Apalachicola River. Flow measurements made using acoustic Doppler current profiling in October 1999 and April 2000 indicate that the "River Boil" discharges about 140 and 210 cubic feet per second, respectively, into the Apalachicola River.



Base from U.S. Geological Survey digital files

(µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter)

0 5 10 MILES

0 5 10 KILOMETERS

Figure 2. Distribution of chemical-constituent concentrations in samples of ground and surface water, Lake Seminole and vicinity, southwestern Georgia and northwestern Florida.

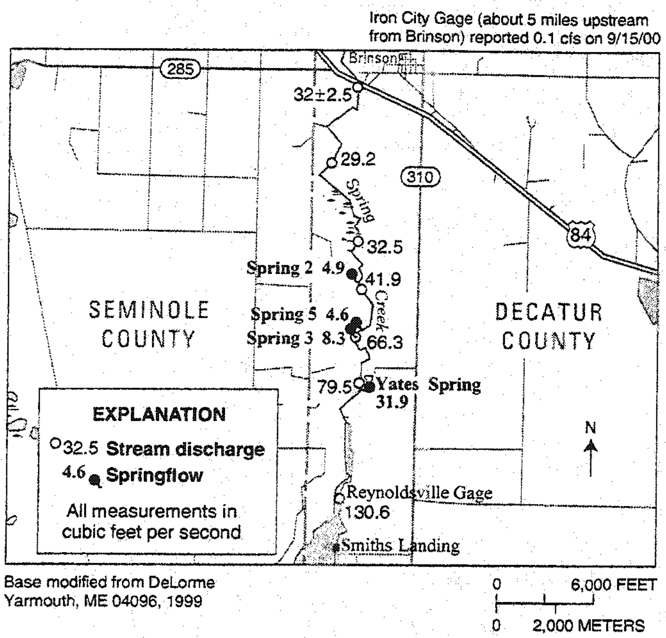


Figure 3. Spring Creek impoundment arm to Lake Seminole showing locations of stream-discharge and springflow measurements made on September 15, 2000.

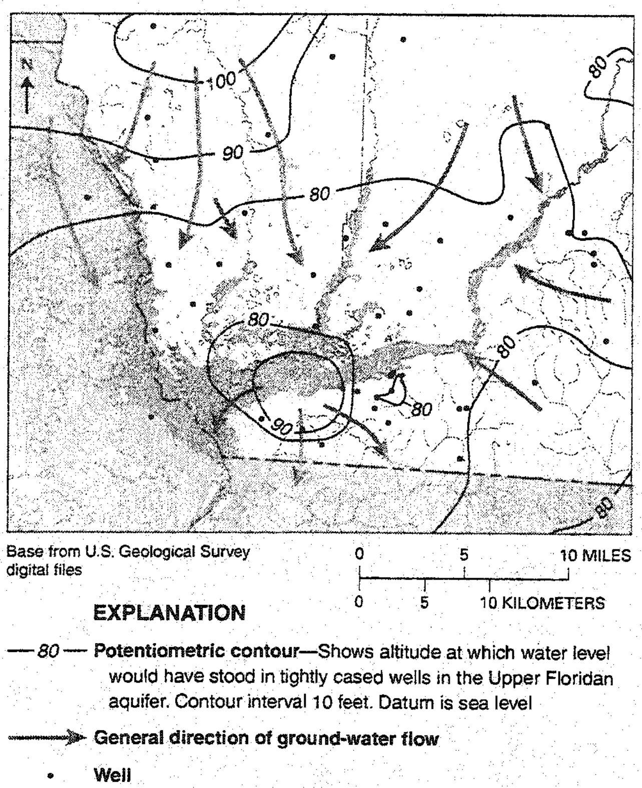


Figure 4. Potentiometric surface of water level in wells completed in the Upper Floridan aquifer, April 2000.

DISCUSSION AND CONCLUSIONS

Water from streams, Lake Seminole, and the Upper Floridan aquifer in the lower ACF River basin has a distinct chemical signature that can be used to investigate flow and mixing processes in and around the lake. Ground-water discharge by diffuse leakage along the four impoundment arms of Lake Seminole and by springflow located in the lake bottom and adjacent to Spring Creek create a complex mixing environment evidenced by hydrochemical data and physical hydrologic characteristics. Although these water-chemistry analyses share similarities with previous water-chemistry studies in the karst environment of the Upper Floridan aquifer in the Suwannee River Basin (Katz and others, 1997; Crandall and others, 1999), the karst features of the Lake Seminole area and the irregular impoundment-arm geometry result in a unique mixing environment for ground-water discharges to the lake. Ground water enters Lake Seminole by diffuse vertical leakage and point inflow from springs. These two main mechanisms for ground-water inflow to the lake are distributed widely along the lake's impoundment arms and preclude detection of downstream water-quality trends in the impoundment arms. Ground water contains higher concentrations of Ca, Mg, and alkalinity, and lower concentrations of TOC and sulfate, which is indicative of carbonate dissolution in the Upper Floridan aquifer. Chemical analyses and physical properties of water sampled from the dam pool and Apalachicola River indicate upwelling of lake water in the river channel downstream of Jim Woodruff Lock and Dam.

The complex interconnection of ground water and surface water in the lower Apalachicola-Chattahoochee-Flint River basin poses several interesting implications relative to the water-allocation negotiations. Thoroughly understanding the mixing dynamics of ground- and surface-water components of the stream-reservoir–aquifer system is essential for developing effective water-management strategies that not only account for these components, but contain provisions to quantify the contribution of each component to the entire flow regime. Mixing model relations based on the distinct chemical signatures of ground water and surface water could be developed in areas where lake leakage is suspected to occur. Such relations would be particularly useful from a water-management and allocation perspective, especially for evaluating ground-water flow near the dam and across the Georgia-Florida State line, where changes in leakage might indicate changes in ground-water flow across the State line and/or increased leakage from the lake. Physical and hydrochemical evidence of ground water mixing with surface water indicates that ground water and surface water form a single hydrologic entity, although each reacts differently with the surface and subsurface environment. Effective management of the basin's water resources will be based on utilizing this scientific knowledge and understanding of the interconnection of ground-water and surface-water flow to develop water-allocation practices that incorporate all components of the stream-reservoir-aquifer system.

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